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I, the undersigned, being duly sworn, depose and state:

The attached translation is an accurate, true and complete rendition into the English language from its original German text, and nothing has been added thereto or omitted therefrom, to the best of my knowledge and belief.




Signature

Tomja B. Hansen

Print Name

Sworn to and subscribed before me

this 22nd day of November, 2005.



Notary Public

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Description

Light Source Element with Lateral Oblique Light Coupling

The invention relates to a light source element pursuant to the preamble to patent claim 1 for backlighting liquid crystal displays, and for use in ambient or background lighting.

In the backlighting of liquid crystal displays, one critical objective is to illuminate the liquid crystal display surface using the most homogeneous monochromatic or polychromatic light beam possible with sufficient luminance. To accomplish this, the beam of light, emitted from one or more light sources, must be distributed over the display surface as homogeneously as possible, while at the same time losses are minimized to the greatest possible extent.

In EP-0 500 960 a flat light source element is described, which is intended for use in backlighting a liquid crystal display. In this light source element, a light source is positioned on one end face surface as an incident light surface of a transparent optical waveguide. One surface of the optical waveguide that is oriented perpendicular to the incident light surface serves as an optical outlet surface, and on the surface of the optical waveguide that is positioned opposite this optical outlet surface a light reflecting layer is arranged. Furthermore, a scattering device is positioned in such a way that the light emitted from the optical outlet surface is diffusely scattered. The homogenization of the light beam over the surface of the light source element is achieved in that one or both surfaces of the optical waveguide are equipped with roughened sections and planar sections, and the area ratio of the roughened to the planar sections changes continuously along the waveguide. The planar sections have the property that they reflect light beams, on the basis of total reflection, back into the waveguide, while on the roughened

sections the light beams are scattered. Since on the optical input side of the optical waveguide the luminance is relatively high at first, a relatively high proportion of planar surfaces is used there, so that in this area the light waves will be projected into the waveguide with a relatively high degree of probability, as a result of multiple total reflection. This surface proportion of planar sections is continuously decreased over the course of the waveguide, so that the light beam can be increasingly scattered on the increasing proportion of roughened surfaces. In this way, a relatively even initial emission can be generated at the optical outlet surface of the light source element.

With the described arrangement, the light beam must be coupled into the optical waveguide on an end face of the light source element. If, for example, a fluorescent tube arranged along this side and encompassed by a metallic reflector is used, then sufficient luminance for the backlighting of a liquid crystal display can be produced with certainty in many cases. However this arrangement is relatively inflexible, as due to the limitation with regard to the usable light source, the luminance cannot be increased beyond a certain level. Furthermore, the placement of the light source at the lateral end face of the light source element is also unfavorable in spatial terms, since the space required for this ultimately limits the width of the display surface of the liquid crystal display.

The objective of the present invention is thus to create a light source element, especially for backlighting liquid crystal displays, which will enable an increase in luminance and in which the positioning of the light sources is not associated with a limitation of the width of the

light-emission surface of the light source element.

Increasing luminance also presents a problem with known-in-the-art light source elements that are used in ambient or background lighting, due to the way in which the beam of light is coupled in at the end faces of the optical waveguide. It is thus a further objective of the present invention to create a light source element for use in background lighting that will have a higher luminance and/or a greater optical outlet surface.

The problems of the current state of the art presented above are solved with a light source element pursuant to patent claim 1.

Common to all embodiments of the present invention is the fact that the light beam is no longer coupled into the optical waveguide at one or both end faces as with the current state of the art, but rather at surfaces that extend lengthwise along the light source element, with the light beam being coupled into the optical waveguide at an oblique angle. Because more space is available along these surfaces for the placement of the light sources, multiple light sources can be provided. This makes it possible for the luminance of a light source element as specified in the invention to be increased.

In all the embodiments the optical waveguide is covered with a reflector at least on the surface that lies opposite the optical outlet surface, and on the side wall surfaces that connect the optical outlet surface and the surface opposite it, with the option that openings may be formed in the reflector to allow the positioning of light coupling units.

In a first embodiment of a light source element as specified in the invention, the light sources are arranged along the side wall surfaces of the optical waveguide. Multiple light sources, such as light-emitting diodes or similar sources, can be arranged along the side wall surfaces, thereby allowing the luminance of the light source element to be increased.

In a second embodiment of a light source element as specified in the invention, the light sources are arranged on the surface of the light source element that lies opposite the optical outlet side. This type of embodiment would be used, for example, as a light source element for background lighting.

The light source elements specified in the invention can, for example, be designed to be flat, in which case they are ideal for use in backlighting liquid crystal displays.

Furthermore, the light source elements of the invention can be used in ambient lighting or background lighting. With the possibility of multiple illumination the attenuation of the optical waveguide is eliminated in practical terms, so that optical waveguides of any length can be illuminated and used for background lighting.

Below, the invention will be described in greater detail with reference to exemplary embodiments depicted in the drawings. The drawings show:

Fig. 1 a first exemplary embodiment of a flat light source element of the invention for use in backlighting liquid crystal displays;

Fig. 2 a cross-section of the light source element of Fig. 1 along the line II-II.

Fig. 3 a second exemplary embodiment of a light source element of the invention for use in background lighting;

Fig. 4 a third exemplary embodiment of a light source element of the invention; Fig. 4a a cross-section along a line IV-IV in Fig. 4;

Fig. 5 a special form of the exemplary embodiment of Fig. 4.

In Fig. 1 an exemplary embodiment of a light source element 10 of the invention is shown, such as can be used, for example, to backlight a liquid crystal display. In Fig. 2 the light source element is depicted in a cross-section along the line II-II in Fig. 1, together with a liquid crystal element.

The core of the light source element 10 shown in Fig. 1 is a flat optical waveguide 1, which in principle can be made of any transparent material, e.g. a thermoplastic resin such as acrylic resin, polycarbonate resin, or even Plexiglas or PMMA. The light that is coupled into this optical waveguide 1 is homogeneously dispersed over the rectangular surface and projected onto a display surface (not shown here) of a liquid crystal display. To this end, the optical waveguide 1 is encompassed on all sides by reflectors 4, with which the incident light beam is diffusely reflected.

The light is coupled-in by means of light coupling units 5, which are positioned in the side wall surfaces 1C and 1D of the light source element 10, and are each comprised of an opening 5B for the allocated reflector 4 and a light source 5A. The light source 5A can be, for example, a semiconducting light-emitting diode (LED) for monochromatic backlighting, but may also be a white light source such as a halogen light or a similar light. In one special embodiment a UV light source can be used, in which case the upper and lower sides of the optical waveguide are coated with a phosphorescent material. The light source

5A is positioned such that the beam of light is radiated into the optical waveguide 1 at a certain oblique angle to a main axis of the waveguide. In this case any angle of arrival may be selected.

Fig. 1 shows an embodiment in which four light coupling units are attached to the optical waveguide 1 on the side wall surface 1C, and two light coupling units are attached on the opposite side wall surface 1D.

In the exemplary embodiment of Fig. 1, for each light coupling unit the optical waveguide 1 has a triangular projection. One side surface of this projection is covered by a reflector 4, while the other side surface lies exposed to the outside, thus forming the opening area 5B.

In the exemplary embodiment of Fig. 1, the end face surfaces 1E and 1F are also advantageously covered with reflectors, so that no light can be coupled out at the end face surfaces.

The reflectors are preferably formed as a single unit and produced via injection molding from Pocan® (thermal polyester with a polybutylene terephthalate base). This material is white and forms an ideal diffuse reflector. However it is also conceivable for a foil material to be applied as a reflector. This may be, for example, a foil with a polycarbonate base that is coated or printed with the color white. To simplify the production process even further the foil could be applied during the injection molding formation of the optical waveguide 10, in which case the form of the injection molding apparatus would be covered with the foil prior to injection molding. When the synthetic mass has hardened, the foil adheres to the waveguide, and can be removed together with it from the injection-molding machine.

The homogenization of the luminance is achieved via the same principle that is used in EP-A-0 500 960 using a variable surface ratio of light diffusing and planar surfaces, which are formed on the optical outlet surface 1A of the optical waveguide 1 and/or on the surface 1B of the optical waveguide 1 that lies opposite the surface 1A, or on both.

In Fig. 2, by way of example, light scattering surfaces 6 and planar surfaces 7 are shown, formed in the optical outlet surface 1A of the optical waveguide. The surface ratio of planar surfaces 7 to light scattering surfaces 6 is dependent upon the luminance at a particular location in the optical waveguide 1. In areas of relatively high luminance in the optical waveguide 1, a relatively high surface ratio is established, while this ratio in areas of relatively low luminance is low. There are multiple possibilities for the form of the light scattering surfaces 6. One particularly simple method of production is to create roughened areas by abrading those surfaces with emery. In areas having a low luminance the surface is abraded comparatively intensively, causing the incident light to scatter. However the light scattering areas 6 can also be small raised areas, for example, which are purposely applied to the surface as a dot matrix. The density distribution in the dot matrix can be determined, for example, using a simulation program, in which essentially the dimensions of the optical waveguide 1 and the locations and intensities of the coupled-in light are input, along with the reflection conditions.

In Fig. 2, a liquid crystal element 9 is also shown, which is positioned above the optical outlet surface 1A of the optical waveguide 1 and is separated from it by means of spacers.

In Fig. 3 a second exemplary embodiment of a light source element 20 as specified in the invention is shown from the side in an enlarged representation. This also represents the second embodiment of the invention, in which the light is coupled-in not via the side wall surfaces but via the surface that lies opposite the optical outlet surface.

As in the first exemplary embodiment, the surface 21B that lies opposite the optical outlet surface 21A, and the side wall surfaces of an optical waveguide 21 are covered with reflectors 24. The statements made in reference to the first exemplary embodiment also apply to these reflectors, i.e. they are preferably formed as a single unit, so that together they form in practical terms a trough-shaped channel in which the optical waveguide 21 is positioned. In the surface 21B that lies opposite the optical outlet surface 21A openings 25B are formed, into which the optical waveguide 21 engages with triangular-shaped projections. In front of these openings 25B, light sources 25A are then arranged in such a way that they are coupled into the optical waveguide 21 at an oblique angle to its main or lengthwise axis. The openings 25B in the reflective layer 24 and their allocated light sources 25A form a multitude of light coupling units 25. In this embodiment the entire surface 21B that lies opposite the optical outlet surface 21A is now available for the positioning of these light coupling units 25, so that a multitude of them can be provided.

Also with this embodiment, for the purpose of homogenizing the light beam, light scattering and planar surfaces can be provided in a variable ratio on the optical outlet surface, as was described in connection with the first embodiment. The light sources can be LEDs or polychromatic white light sources.

The exemplary embodiment shown in Fig. 3 can be used, for example, as an extended light source element for an ambient background.

Especially, several of the units shown can be arranged one in front of another to produce any desired length.

A further exemplary embodiment is shown in Fig. 4. This exemplary embodiment relates to the first embodiment of the invention, as here again the light is coupled-in on the side wall surfaces of the light source element. Shown here is a portion of the light source element 30, which in principle can be formed in any desired length. The light source element 30 can be used, for example, for ambient or background lighting.

In Fig. 4a, the light source element 30 is shown in cross-section along the line IV-IV in Fig. 4. According to this diagram, the optical waveguide 31 has an optical outlet surface 31A and is covered on the opposite surface and on the side wall surfaces with reflectors 34. The same statements apply to these reflectors as in the exemplary embodiments described above. The reflector 34 is interrupted along a side wall surface by specific opening areas 35B, in front of which light sources 35A are arranged such that the beam of light they emit penetrates the optical waveguide 30 at an oblique angle to its lengthwise axis. The opening areas 35B in the reflector 34 and the light sources 35A positioned in front of them form light coupling units 35. The light sources 35 can - as in the preceding exemplary embodiments - be comprised of LEDs or polychromatic white light sources.

It has proven particularly beneficial for the reflector 34 to project into the optical waveguide, spaced slightly from the open surface of the optical waveguide 31 in the opening area 35B. In this way, the formation of bright luminous effects ("hot spots") in the optical waveguide 31 in the area near the light source 35 can be prevented.

The rounded shape of the reflector surfaces, which are positioned at an angle to form the opening areas 35B, has proven further beneficial to the coupling-in of light. This also applies to the embodiment of Fig. 3.

Furthermore, with this type of light source element light attenuation is no longer a factor in practical terms, and light source elements of any shape and length may be formed.

In Fig. 5, a special exemplary embodiment of the light source element shown in Fig. 4 is presented. This embodiment has a closed form, wherein on its inner circumferential surface a multitude of light coupling units 45 are provided, arranged one in front of another (the light sources are not shown here). The structure and the design of the optical waveguide 40 are as shown in Fig. 4. The special design of the closed ring can have any shape.

Patent Claims

1. Light source element (10, 20, 30, 40), with
 - an optical waveguide (1, 21, 31), which
 - comprises an optical outlet surface (1A, 21A, 31A),

c h a r a c t e r i z e d i n t h a t

 - the surface (1B, 21B, 31B) of the optical waveguide (1, 21, 31) that lies opposite the optical outlet surface (1A), and the side wall surfaces (1C, 1D) of the optical waveguide (1, 21, 31) that connect the optical outlet surface (1A, 21A, 31A) and the opposite surface (1B, 21B, 31B) are each covered with light-reflecting or diffuse reflecting reflectors (4, 24, 34),
 - on the side wall surfaces (1C, 1D) or the surface (1B) of the optical waveguide (1, 21, 31) at least one light coupling unit (5, 25, 35, 45) is arranged,
 - which comprises an opening area (5B, 25B, 35B) for the allocated reflector (4, 24, 34) and a light source (5A, 25A, 35A) arranged in front of the opening area (5B) such that
 - the beam of light that is emitted from the light source (5A) during operation penetrates the optical waveguide (1, 21, 31) at an oblique angle.
2. Light source element (10, 20, 30, 40) pursuant to claim 1,
c h a r a c t e r i z e d i n t h a t
 - in at least one side wall surface (1C, 1D) or the surface (1B) of the optical waveguide (1, 21, 31) at least one triangular projection is formed,
 - one side surface of which is covered by a reflector (4, 24, 34) while
 - the other side surface lies open toward the outside and thus forms the opening area (5B, 25B, 35B).
3. Light source element (10, 20, 30, 40) pursuant to claim 1,
c h a r a c t e r i z e d i n t h a t

- the optical outlet surface (1A) and/or the surface (1B) of the optical waveguide (1) that lies opposite it comprises light scattering sections (6) and planar sections (7),
- and the surface ratio of the planar sections (7) to the sections (6) along the optical waveguide (1) is adjusted such that an even luminance of the light source element (10) is achieved.

4. Light source element (10, 20, 30, 40) pursuant to claim 1, characterized in that

- the reflectors (4, 24, 34) are connected to one another as single units.

5. Light source element (10, 20, 30, 40) pursuant to claim 1 or 4, characterized in that

- the material of the reflectors (4, 24, 34) can be injection molded and the reflectors (4, 24, 34) are produced via the injection molding process.

6. Light source element (10, 20, 30, 40) pursuant to claim 1, characterized in that

- the material of the reflectors (4, 24, 34) is formed from a thermoplastic polyester, especially one with a polybutylene terephthalate base.

7. Light source element (10, 20, 30, 40) pursuant to claim 1, characterized in that

- the material of the reflectors (4, 24, 34) is Pocan®.

8. Light source element (10, 20, 30, 40) pursuant to claim 1, characterized in that

- the reflectors (4, 24, 34) are formed from a foil material, especially one with a polycarbonate base, and the foil material is coated or printed with the color white.

9. Light source element (40) pursuant to claim 1,
c h a r a c t e r i z e d i n t h a t

- it forms a closed ring.

10. Light source element (10, 20, 30, 40) pursuant to one or more of
the preceding claims,

c h a r a c t e r i z e d i n t h a t

- at least one light source (5, 25, 35, 45) is a semiconductor light-emitting diode.

11. Liquid crystal display with a light source element (10) pursuant
to one or more of the preceding claims,

c h a r a c t e r i z e d i n t h a t

- a liquid crystal element (9) is positioned on the side of the optical outlet surface (1A).

12. Liquid crystal display pursuant to claim 11,

c h a r a c t e r i z e d i n t h a t

- the liquid crystal element (9) is held a certain distance from the optical outlet surface (1A) by means of spacers.

Abstract

Light Source Element with Lateral Oblique Light Coupling

The invention describes a light source element (10, 20, 30, 40), which can be used for backlighting liquid crystal displays or for ambient or background lighting. Pursuant to the invention it is provided that the beam of light is coupled into the allocated optical waveguide (1, 21, 31) either through a side wall surface or through a surface (1B, 21B) of the optical waveguide (1, 21, 31) that lies opposite the optical outlet surface (1A, 21A, 31A). On these surfaces the optical waveguide (1, 21, 31) is surrounded by reflectors (4, 24, 34), in which suitable opening areas (5B, 25B, 35B) may be formed. This enables the arrangement of a multitude of light sources (5, 25, 35, 45) and thus a corresponding increase in luminance.

Fig. 1

List of Reference Figures

- 1 Optical waveguide
- 1A Optical outlet surface
- 1B Surface
- 1C Side wall surface
- 1D Side wall surface
- 1E End face surface
- 1F End face surface
- 4 Reflector
- 5 Light coupling unit
- 5A Light source
- 5B Opening area
- 10 Light source element
- 20 Light source element
- 21 Optical waveguide
- 24 Reflector
- 25 Light coupling unit
- 25A Light source
- 25B Opening area
- 30 Optical waveguide
- 34 Reflector
- 35 Light coupling unit
- 35A Light source
- 35B Opening area
- 40 Light source element
- 45 Light coupling unit

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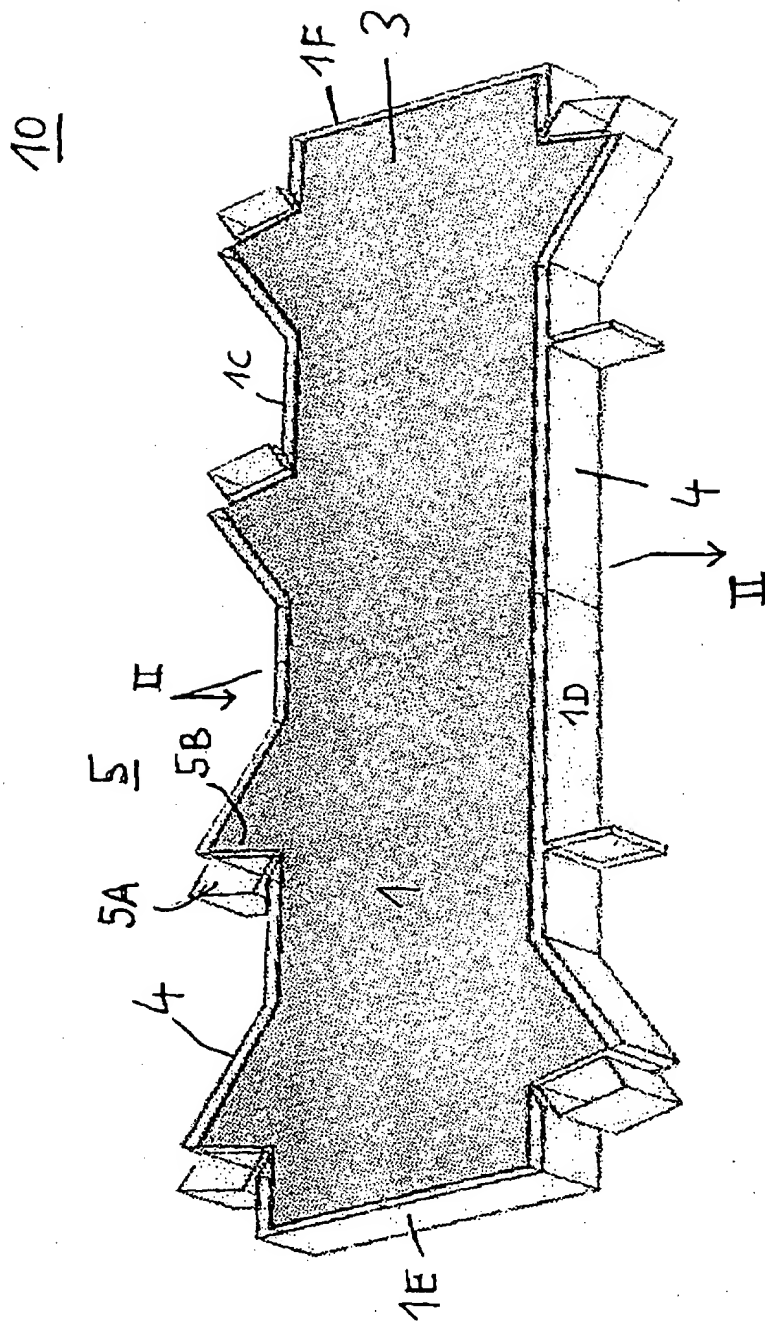


Fig. 1

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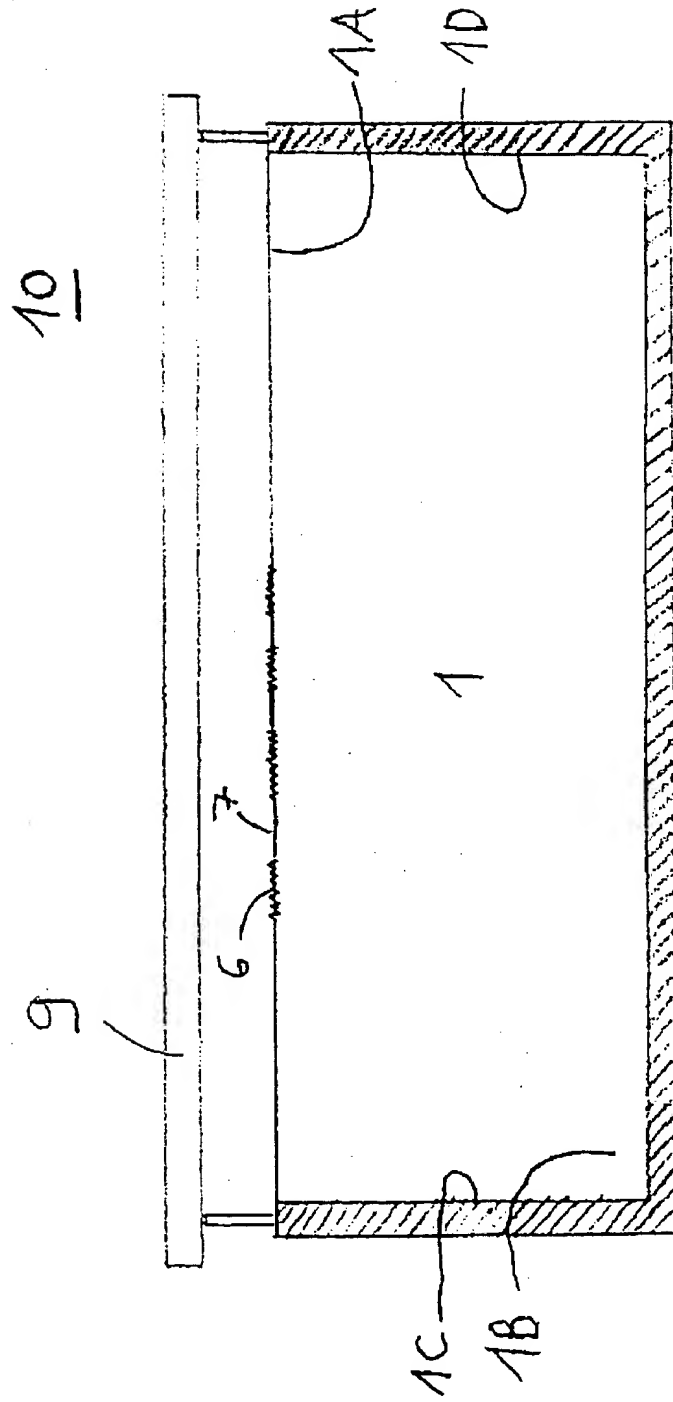


Fig. 2

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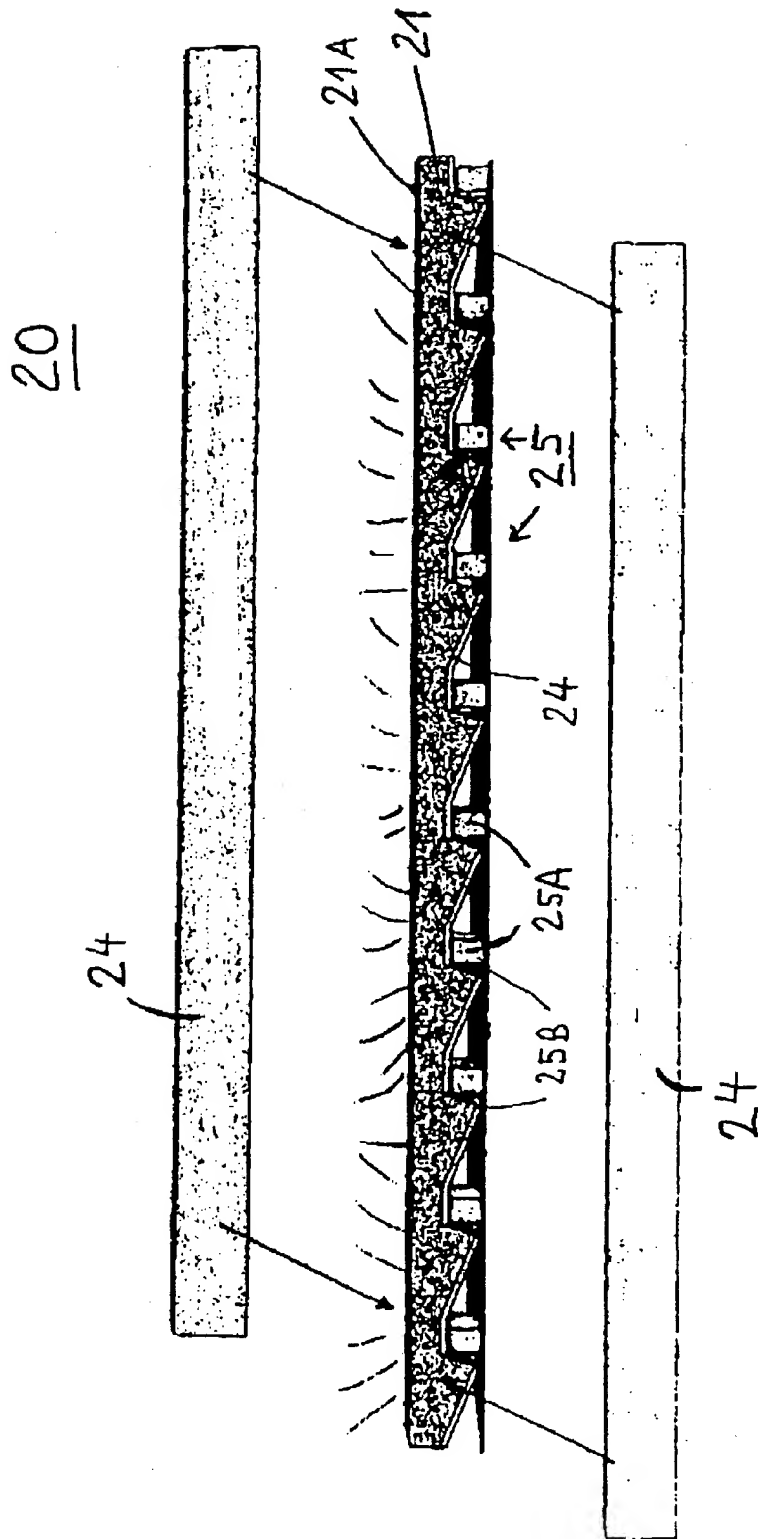


Fig. 3

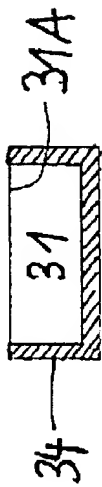


Fig. 4a

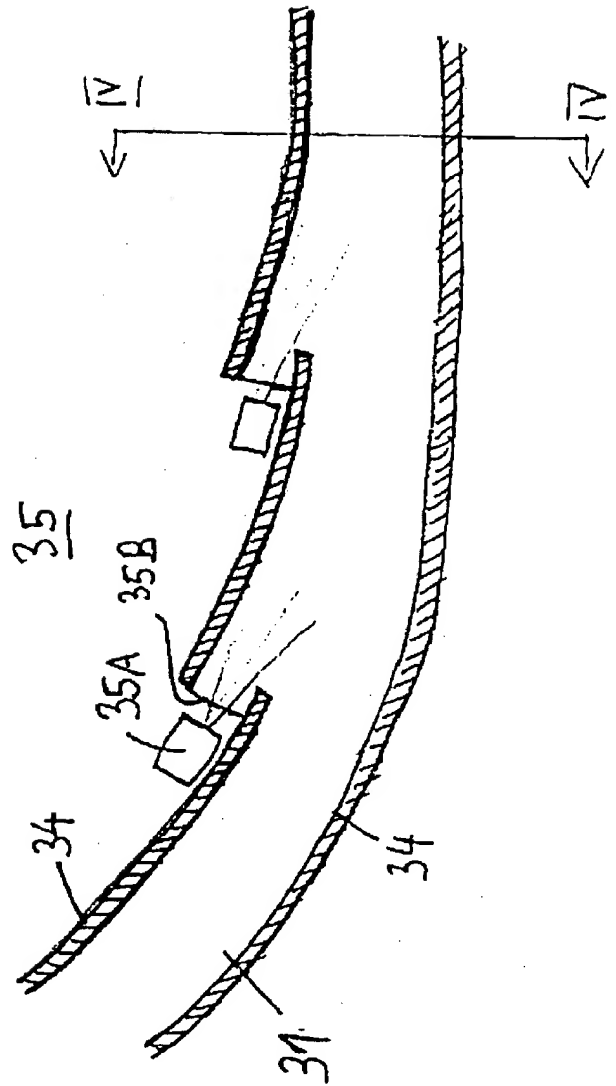


Fig. 4

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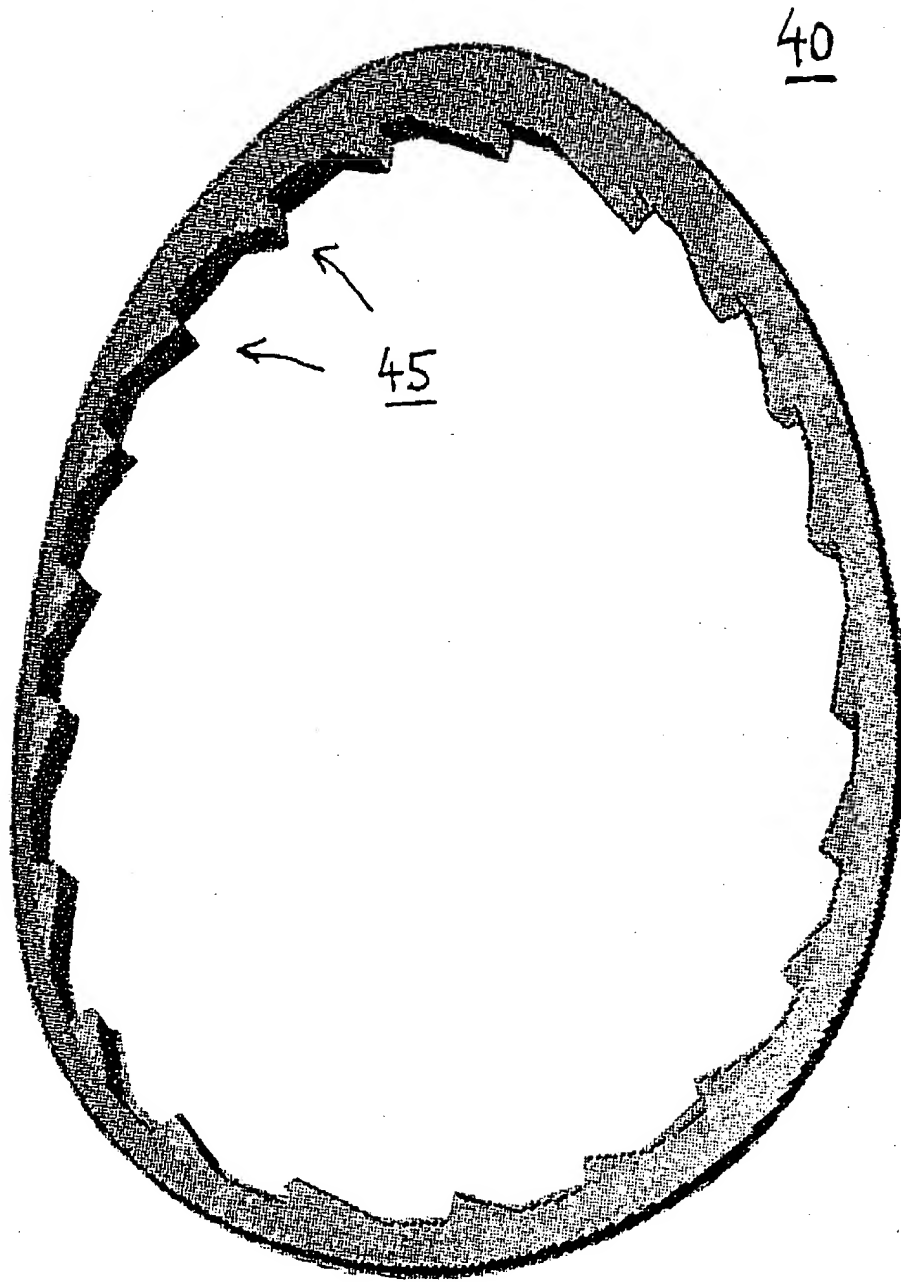


Fig. 5